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Notes on morphological variation and the biology of *Nototriton guanacaste* Good & Wake, 1993 (Caudata, Plethodontidae)

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The variation in body size, body proportions, and coloration of *Nototriton guanacaste* Good & Wake, 1993 is greater than documented previously. Data from seven newly collected specimens suggest that the character "snout-gular length", previously considered to be diagnostic, widely overlaps with that of other Costa Rican *Nototriton* species. The variation of some aspects of coloration is considerably greater than in the type series. Regarding the habitat, *N. guanacaste* seems to prefer locations among roots of epiphytes growing in moss mats.

INTRODUCTION

Despite the comprehensive study of GOOD & WAKE (1993), the diminutive and inconspicuous plethodontid salamanders of the genus *Nototriton* are among the least known species of the Costa Rican amphibian fauna. I collected specimens of the recently described *Nototriton guanacaste* Good & Wake, 1993, which is endemic to two isolated peaks in northwestern Costa Rica. This material provides new information on morphological variation with respect to body size, body proportions, coloration and on habitat and biology

MATERIAL AND METHODS

Specimens of *Nototriton guanacaste* here studied are deposited in the collection of the Zoologisches Forschungsinstitut und Museum Alexander Koenig, Bonn, Germany (ZFMK). Seven specimens and two clutches were collected at the type locality in Guanacaste National Park, Costa Rica, in the western summit area of Cerro Cacao (1450-1550 m) on 7 September 1993 (ZFMK 67726), 13 September 1993 (ZFMK 67728) and 23 September 1993 (ZFMK 67727, 57729-57732). Furthermore, the material consists of a clutch of eight eggs deposited on 7 September 1993 (three preserved on 7 September 1993: ZFMK 57733; five preserved on 12 October 1993: ZFMK 57734) and a clutch of five eggs found on 23 September 1993 (one

preserved on 23 September 1993. ZFMK 57735; four preserved on 12 October 1993. ZFMK 57736). Measurements follow the standards defined by BRAME (1968), and were made under a dissecting microscope fitted with an ocular micrometer.

RESULTS

MORPHOLOGY

Measurements and morphometric dimensions of the newly collected material are shown in tab. 1. Most of the newly ascertained body measurements and proportions (axilla-groin length, head width, nostril diameter, forelimb length, hindlimb length, foot width, third and fifth toe length) agree well or are at least very near to those of the type series. However, maximum length and variation of some body proportions are larger than previously documented. Three of the seven newly collected specimens have larger snout-vent lengths than the largest specimens of the type series (holotype, 29.7 mm). Furthermore relative trunk width is consistently larger in the newly collected material, with no overlap with the range of the type series. In contrast, relative tail length is shorter in the newly collected material, likewise with no overlap with the range of the type series. With respect to the relative snout-gular length ("head length"), only the two smallest specimens are near to measurements of the type specimens, with head lengths of 20 3 and 21 3 percent of snout-vent length. Relative snout-gular length is strongly negatively correlated with snout-vent length (r = -0 88; P = 0.004). Regarding the development of the parotoid glands, only a somewhat physically enlarged parotoid region is discernible in all specimens of the new material.

The preserved specimens are shown in fig. 1. Two specimens (ZFMK 57726 and 57732) show a conspicuous bright dorsal ground coloration, which was light brownish-orange in life. Within the entire series, the lateral and dorsal ground color varied from light brownish-orange to dark brown in life. One of the seven new specimens (ZFMK 57731) has a bright lateral coloration In two specimens (ZFMK 57727 and 57729), the flanks are slightly brighter than the dark brown dorsum, whereas the four remaining specimens have a lateral coloration which is identical (ZFMK 57728) or darker than the dorsal ground color. The bright coloration of the parotoid region is evident in all the new specimens. However, a bright elongate blotch on the parotoids is indistinct and very small in ZFMK 57728 and 57730. In ZFMK 57726 and 57732, parotoid glands cannot be discerned by their color due to an overall bright dorsal coloration

NOTES ON BIOLOGY

All specimens of *Nototriton guanacaste* were observed in 10-20 cm thick dripping wet moss mats growing on trees in "lower montane rain forest" (sensu TOSI, 1969 common names, "cloud forest", "elfin forest") near the summit of Cerro Cacao. During 12 hours of searching, three salamanders were taken from moss clumps hanging from twigs and branches, whereas four specimens were found within 30 minutes on horizontal branches among the

Table 1 – Measurements (mm), followed in parentheses by morphometric ratios (percent of snout-vent length), of the seven newly collected *Nototriton guanacaste* specimens compared with the range of the type series (after GOOD & WAKE 1993) SVL: snout-vent length.

	ZFMK 57727	ZFMK 57729	ZFMK 57726	ZFMK 57728	ZFMK 57731	ZFMK 57730	ZFMK 57732	Range % SVL (hoc loco)	Range % SVL (type series)
Sex	male	male	female	female	female	cf. female	cf female		
Snout-vent length	30.9	26.8	33.5	33.0	27.5	22.2	22.1	–	–
Axilla-groin length	17.7 (57.3)	14.0 (52 2)	20.0 (60 6)	20 0 (59 7)	15.7 (57.1)	12 0 (54 1)	12.3 (55.7)	52.2 – 60.6	54.5 56.3
Trunk width	4 7 (15.2)	4.0 (14.9)	4 5 (13.6)	5.0 (14.9)	4.0 (14.5)	3.2 (14.4)	3.3 (14.9)	13 6 – 15.2	11.0 12.2
Tail length	–	–	39.0 (116.4)	–	28.9 (105.1)	24.6 (110.8)	23.9 (108.1)	105.1 116.4	121 0 133 7
Snout-gular length	5 8 (18 8)	5 2 (19.4)	6.1 (18 5)	5.9 (17.6)	5.0 (18.2)	4.5 (20 3)	4.7 (21.3)	17.6 21.3	21.6 – 22.4
Head width	4 1 (13 3)	3.9 (14.6)	4.2 (12.7)	4.4 (13 1)	3.8 (13.8)	3.3 (14.9)	3.5 (15.8)	12.7 – 15 8	14.5 – 15.7
Nostril diameter	0 24 (0.78)	0.19 (0.71)	0.12 (0 36)	0 19 (0 57)	0.17 (0.62)	0 21 (0 95)	0.21 (0.95)	0 36 0 95	0 4 0.9
Forelimb length	5 8 (18 8)	4 6 (17 2)	5 6 (17.0)	5.3 (15.8)	4 2 (15 3)	3.8 (17.1)	3 9 (17 6)	15 3 – 18.8	17 0 – 17.9
Hindlimb length	6 4 (20 7)	5 3 (19 8)	5 8 (17 6)	5.8 (17.3)	4 8 (17 5)	4.4 (19.8)	4 4 (19.9)	17.3 – 20.7	18.5 – 20.1
Foot width	2 5 (8 1)	2 0 (7 5)	2 3 (7 0)	2.1 (6 3)	1 9 (6 9)	1.3 (5 9)	1 5 (6.8)	5.9 – 8 1	6.6 – 7.2
Third toe length	1 0 (3.2)	0.9 (3.4)	1 2 (3 6)	0 9 (2.7)	0 8 (2 9)	0 7 (3.2)	0.6 (2.7)	2.7 – 3.6	2.8 3.1
Fifth toe length	0 6 (1.9)	0.4 (1.5)	0 6 (1.8)	0 5 (1 5)	0.5 (1.8)	0 3 (1.4)	0 3 (1 4)	1.4 – 1.8	1.1 – 1.7

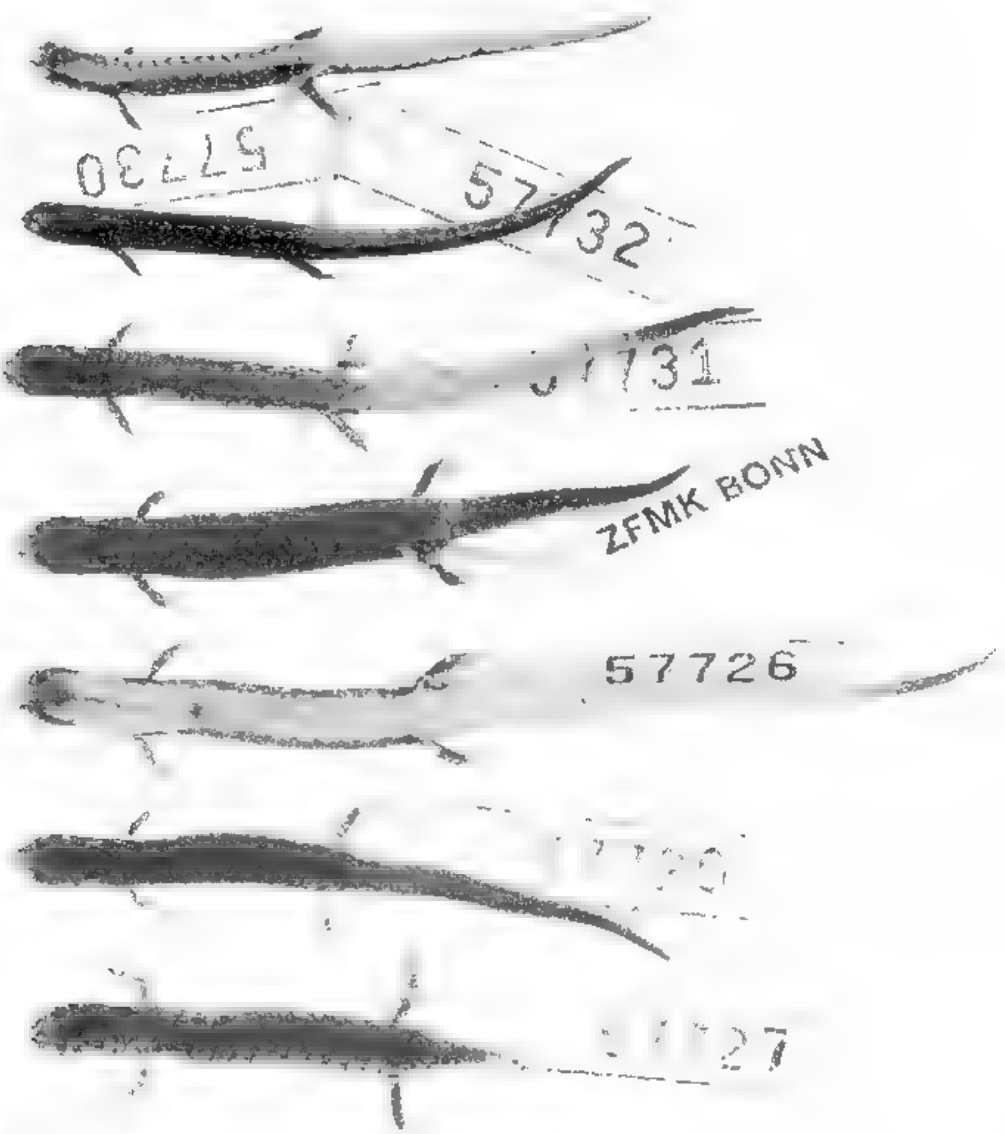

Fig. 1 Variation in coloration in *Nototriton guanacaste* from Cerro Cacao (Guanacaste, Costa Rica). Photo: Juliane Popp

roots of epiphytes growing in the moss mats. In such microhabitats, the habitus of the salamanders was remarkably similar to that of epiphytic roots. All animals were found 0.5 to 5 meters above the ground. Substrate temperatures ranged from 18.6 to 21.5°C.

When grasped, all salamanders showed "coil-uncoil flip" and "running flip" defensive behaviors (Dodd & Brodie, 1976). Flips were observed as far as 50 cm.

On 7 September 1993, female ZFMK 57726 and two single eggs were taken from a moss clump growing on an air root two meters above the ground. The night after capture, the female deposited six eggs in the moss of the transportation container. An unguarded clutch of five eggs, containing well developed embryos, was taken on 23 September 1993 from a moss mat

growing on a vertical tree trunk about two meters above the ground. Both clutches were stored in wet moss at room temperature in the laboratory for a time. Most eggs of both clutches developed well until they were perserved.

DISCUSSION

Most of the here ascertained differences in morphometric dimensions are not surprising, since only five individuals of *N. guanacaste* were analyzed in the original description by GOOD & WAKE (1993) The data on the snout-vent lengths of the new specimens suggest that those of the type series are not fully grown, though obviously mature (according to GOOD & WAKE, 1993: 138, one male specimen of the type series has a "rather flat and inconspicuous mental gland"). The new ascertained maximum snout-vent length of 33.5 mm (female, ZFMK 57726) makes *N. guanacaste* the second largest among the Costa Rican *Nototriton* species. Only the single known specimen of *N. major* Good & Wake, 1993 has a larger size with a snout-vent length of 37.9 mm. Differences in relative tail lengths of the new specimens compared to the types may be caused by slightly different measurements. I measured snout-vent length from the anterior tip of the snout to the posterior angle of vent. If measured to the anterior angle of vent (and subsequently tail length from anterior angle to the tip of the tail), the new specimens have relative tail lengths of 112.8 to 128.9 (mean 122.5 ± 7.12) percent of snout-vent length This is well within the range of the data given in the original description. Relative snout-gular length is a major diagnostic feature which separates *N. guanacaste* from all other Costa Rican *Nototriton* (GOOD & WAKE, 1993). The revised range of 17.6 to 22.4 percent in this character (including data from GOOD & WAKE, 1993) widely overlaps with *N. picadoi* (Stejneger, 1911), *N. richardi* (Taylor, 1949), *N. tapanti* Good & Wake, 1993, *N. major* Good & Wake, 1993 and various populations of *N. abscondens* (Taylor, 1948). The differences between my own data and those of GOOD & WAKE (1993) can be explained by the smaller size of the type specimens (see above): relative snout-gular length is significantly negatively correlated with snout-vent length. In other words, smaller animals have longer heads and head length shows a changing relationship to body size as animals grow. Another diagnostic feature which separates *N. guanacaste* from *N. abscondens* according to GOOD & WAKE (1993) is its prominent parotoid glands. I ascertained only rather flat and inconspicuous parotoid regions in the new material However, it is relative to some degree to regard a character as "prominent" or "indistinct", and the difference may be caused by my limited experience with other *Nototriton* species. A single specimen of *N. abscondens* (El Angel Waterfall, Provincia de Alajuela, Costa Rica, in my private collection) indeed shows much more reduced, almost invisible parotoid glands.

The robust habitus (as measured by "trunk width") of *N. guanacaste,* that makes it unmistakable among Costa Rican species, is confirmed by the newly collected material. The revised range with a maximum of 15.2 percent of snout-vent length even emphasizes differences to the other species. However, one should keep in mind that differences between the new material and the type series may be caused by different methods of conservation.

All in all the robust habitus and the confirmed small nostril diameter (which is a major character separating *N. guanacaste* from the geographically nearest population of

N. abscondens at Monteverde) support the specific status of *N. guanacaste* from the morphological point of view.

Variation in coloration of the newly collected specimens is considerably greater than in the type series. A bright lateral coloration, as reported in previously collected specimens, is evident in only one specimen. Bright parotoid blotches are indistinct and very small in two specimens. GOOD & WAKE (1993) mentioned that these markings were less evident in their smaller specimens. However, markings are inconspicuous among the new material in one large (ZFMK 57728) and one small specimen (ZFMK 57730).

The observations regarding the biology agree well with data known for *N. guanacaste* and other *Nototriton* species. Like all previously observed specimens, the new material was found in moss mats on trees above the ground. Regarding the microhabitat, the new specimens were observed with different success in two different structures: in moss clumps hanging from air roots or growing on vertical branches (0.25 specimen/hour) and in moss mats among roots of epiphytic ferns and bromeliads on horizontal branches (8 specimens/hour). Due to the small number of observed specimens, these results may be accidental. Nevertheless, it can be considered that humidity conditions are more stable in the latter microhabitat due to a higher proportion of humus and an overall thicker and more compact substrate cover.

The defensive behaviors "coil-uncoil flip" and "running flip" were previously reported by DODD & BRODIE (1976) for other neotropical plethodontids, including "*Chiropterotriton picadoi*" (i.e., *Nototriton richardi* or *N. abscondens* sensu GOOD & WAKE, 1993). I observed that juvenile and adult *N. picadoi* and *N. abscondens* show the same behaviors in the field and in captivity.

The clutch sizes of five and eight eggs observed during the present study correspond to the data given by GOOD & WAKE (1993): two clutches with four and seven eggs. In other *Nototriton* species, clutch size may be as high as 17 eggs (JOKUSCH & GARCIA-PARIS, 1998).

Nototriton and *Oedipina* are presumed to be the only bolitoglossines which abandon their clutches (GOOD & WAKE, 1993). The finding of another unguarded clutch of *N. guanacaste* supports this to some degree. It should be noted that I also found two further unguarded clutches (with two and three eggs) of unidentified *Nototriton* on 3 and 4 October 1993 at Tapanti, Costa Rica.

Though considerably different to the type series in some aspects, I regard the newly collected material as belonging to a single species. Differences in morphometric dimensions are consistent among the newly collected material (tail length) or vary gradually (snout-gular length). Furthermore, differences in coloration (parotoids and flanks) are not associated with differences in body proportions or snout-vent length. *Nototriton* species can be highly specific to microhabitats (see CAMPBELL & SMITH, 1998), so the different microhabitats observed in the present study may give a hint for a specific differentiation. However, the occurrence of color morphs (e.g., animals with dark flanks or animals with a bright overall coloration) did not correspond to a certain type of microhabitat.

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